

Laser Sounder for Global Measurement of CO₂ Concentrations in the Troposphere from Space: Progress

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Abstract - We are developing a laser technique for the remote measurement of the tropospheric CO₂ concentrations from orbit. Our goal is to demonstrate a laser technique and instrument technology that will permit measurements of the CO₂ column abundance in the lower troposphere from aircraft at the few parts per million (ppm) level, with a capability of scaling to permit global CO₂ measurements from orbit.

I. INTRODUCTION

We propose a laser sounding technique that will enable a new generation of atmospheric CO₂ measurements from orbit. We propose to optimize the new measurement system to address outstanding questions in carbon cycle research through coordinated modeling and sensitivity testing. The need for measurements of atmospheric CO₂ via the laser sounder is specifically stated in the NASA Earth Science Enterprise strategy. Our proposed mission directly addresses the NASA Carbon Cycle and Ecosystems focus area roadmap for High-Resolution Atmospheric CO₂ for deployment in 2012. This mission is to characterize CO₂ sources and sinks on a sub-regional spatial scale in near real-time. Achieving this objective will require significant advances in measurement technology relative to current and planned missions for CO₂.

II. MEASUREMENT TECHNIQUE

The current state of the art for space-based remote sensing of atmospheric CO₂ is the Orbiting Carbon Observatory (OCO), scheduled for launch in 2008. OCO is a NASA ESSP mission for measuring total column CO₂ and O₂ by detecting absorption in reflected sunlight [1]. Although OCO will yield important new information about the distribution of atmospheric CO₂, there are unavoidable physical limitations

imposed by the passive measurement approach that include: daytime/high sun only sampling, interference by cloud and aerosol scattering, and limited signal variability in the CO₂ column. The proposed laser sounder mission, consisting of laser remote sensing of CO₂, O₂, and aerosol and cloud properties, overcomes the most serious of these limitations to provide: 1) full seasonal sampling to high latitudes, 2) flexible day/night sampling, 3) greatly reduced uncertainty/bias in CO₂ from atmospheric (cloud and aerosol) scattering, 4) ability (limited) to resolve the altitude distribution of CO₂.

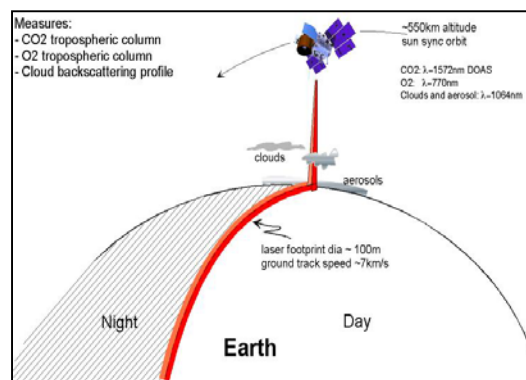


Figure 1 illustrates the laser sounder

Fig. 1 Laser Sounder Concept

concept. The CO₂ absorption band in the 1570 nm region is nearly free from interferences by other species and is characterized by absorption cross-sections that are strong enough to provide sensitivity to small changes in the CO₂ mixing ratio for a nadir viewing satellite instrument. Absorption by CO₂ in a column between the earth's surface and the satellite may be measured by rapidly pulsing a laser on and off an absorption line and measuring the surface echo

by using direct detection as illustrated in Figure 1. The ratio between the on- and off-line echo energies yields the fractional absorption by the column. This approach is similar to the Differential Absorption Lidar (DIAL) technique, which has been used for many measurements of atmospheric trace species. Traditional DIAL measures photons backscattered from air molecules or atmospheric aerosols, while our technique measures the backscatter from the Earth's surface, which is stronger by a factor of 1000 or more. Absorption by O₂ will be measured in a similar manner by a second co-boresighted laser using absorption in the O₂ A-band near 769 nm. From space, a third laser at 1064 nm would be used for detecting clouds and profiling aerosol backscatter. This allows cloud-free scenes to be unambiguously identified and the effects of aerosol and cirrus back-scatter to be accounted for. This is a major advantage of our approach compared to passive methods. From space, our method will provide column average CO₂ abundance weighted to the lowest 4 km of the troposphere. Collocated measurements of O₂ column abundance will allow us to account for variations in the CO₂ absorption path caused by topography, surface pressure changes, and variable humidity (as well as having major independent benefit to weather analysis and forecasting). Co-aligned measurement of aerosol and cloud scattering properties will allow us to more precisely account for scattering effects [2]. Our method can measure at all latitudes at any sun angle, e.g., dawn and dusk, and is more robust against bias caused by diurnal variations in surface CO₂ mixing ratios.

III. PROGRESS

Although the CO₂ absorption band in the 1570 nm region is nearly free from interferences by other species it is crucial that the most suitable line is selected for the sounder approach. The spectroscopic conditions that must be met (minimal temperature sensitivity, negligible interferences from other species, etc.) are analyzed in detail [3]. In addition to the spectroscopic requirements, the wavelength must be easily accessible with the current state of component transmitter and receiver technology. Using the above criteria we selected a candidate line near 1572.33 nm and we have been successful in locking the laser wavelength to

within ± 0.1 pm of the candidate line using a wavemeter (EXFO WA-1650) and very simple software control loop. An alternative, more conventional locking technique, using fiber cells will also be investigated.

The laser sounder makes absolute spectroscopic measurements of the CO₂ mixing ratio. Like any active spectrometer it is extremely sensitive to fluctuations in the transmitter power. Knowledge of the transmitted power to 0.1 % is crucial if the science requirement of 1 ppm accuracy is to be met. We have been conducting extensive experiments to identify and minimize any spurious sources of noise and drifts in our system. We have been successful in achieving a 0.3% stability power monitor over 6-8 hours. We hope to improve on the performance of the monitor using signal processing techniques and precise control of the engineering parameters of the system.

We have also made considerable progress on the oxygen channel. We have been successful in doubling 1540 nm radiation from a fiber amplifier using a Periodically-Poled (PP) Potassium Titanium Oxide Phosphate (KTP) and measure some of the candidate O₂ lines at 770 nm.

On the receiver side we have identified four different candidate detectors and tested three of them with very encouraging results. We hope to test the fourth one shortly. Some detectors are commercially available some are experimental devices.

In summary, we have made considerable progress in the system design and component technology of the laser sounder. We have also investigated the impact of the science requirements on the system design.

REFERENCES

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